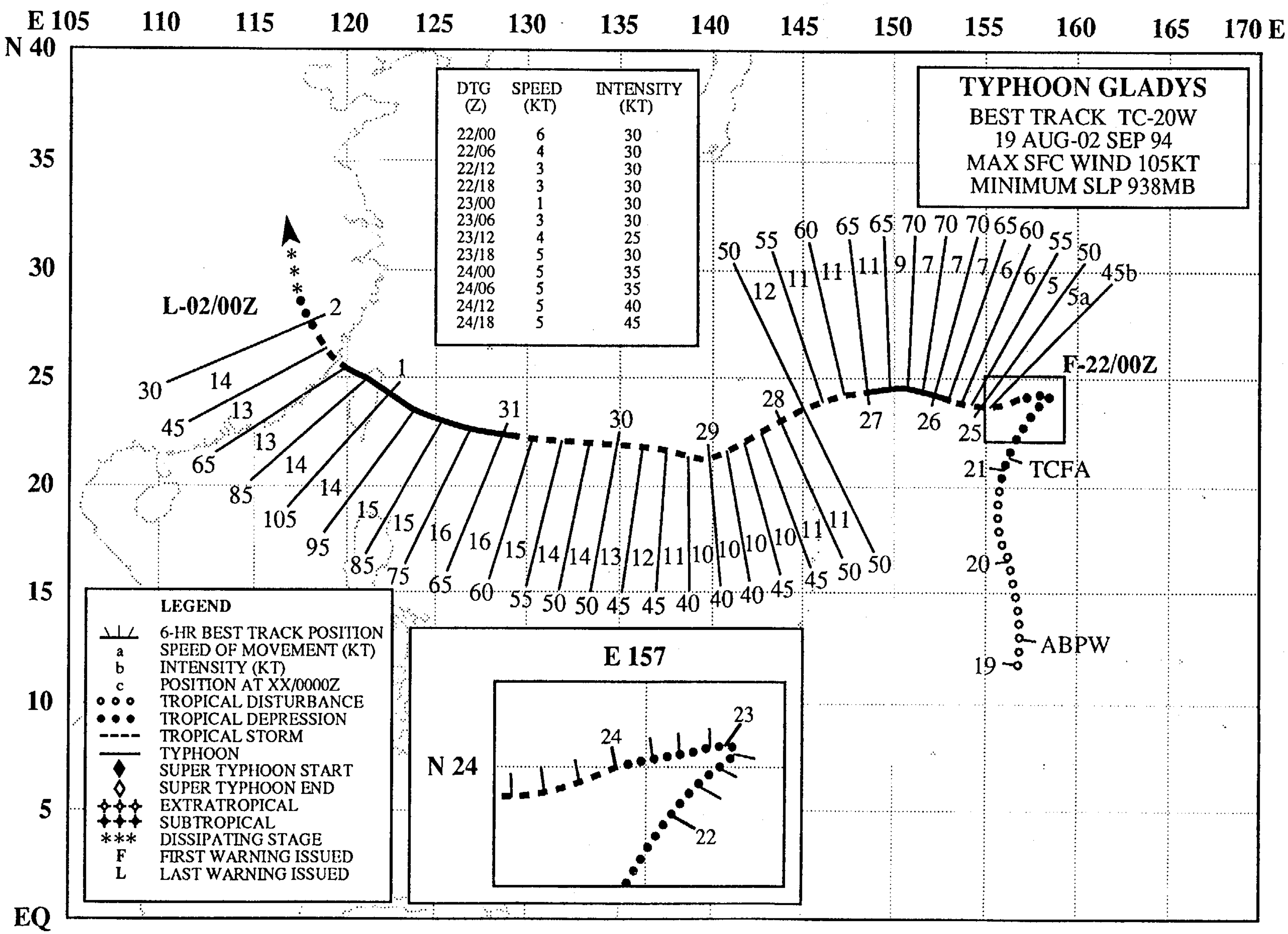
TYPHOON GLADYS
BEST TRACK TC-20W
19 AUG-02 SEP 94
MAX SFC WIND 105KT
MINIMUM SLP 938MB
DTG (Z) SPEED (KT) INTENSITY (KT)
22/00 6 30
22/06 4 30
22/12 3 30
22/18 3 30
23/00 1 30
23/06 3 30
23/12 4 25
23/18 5 30
24/00 5 35
24/06 5 35
24/12 5 40
24/18 5 45
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L-02/00Z
F-22/00Z
TCFA
ABPW
E 157
N 24

TYPHOON GLADYS (20W)

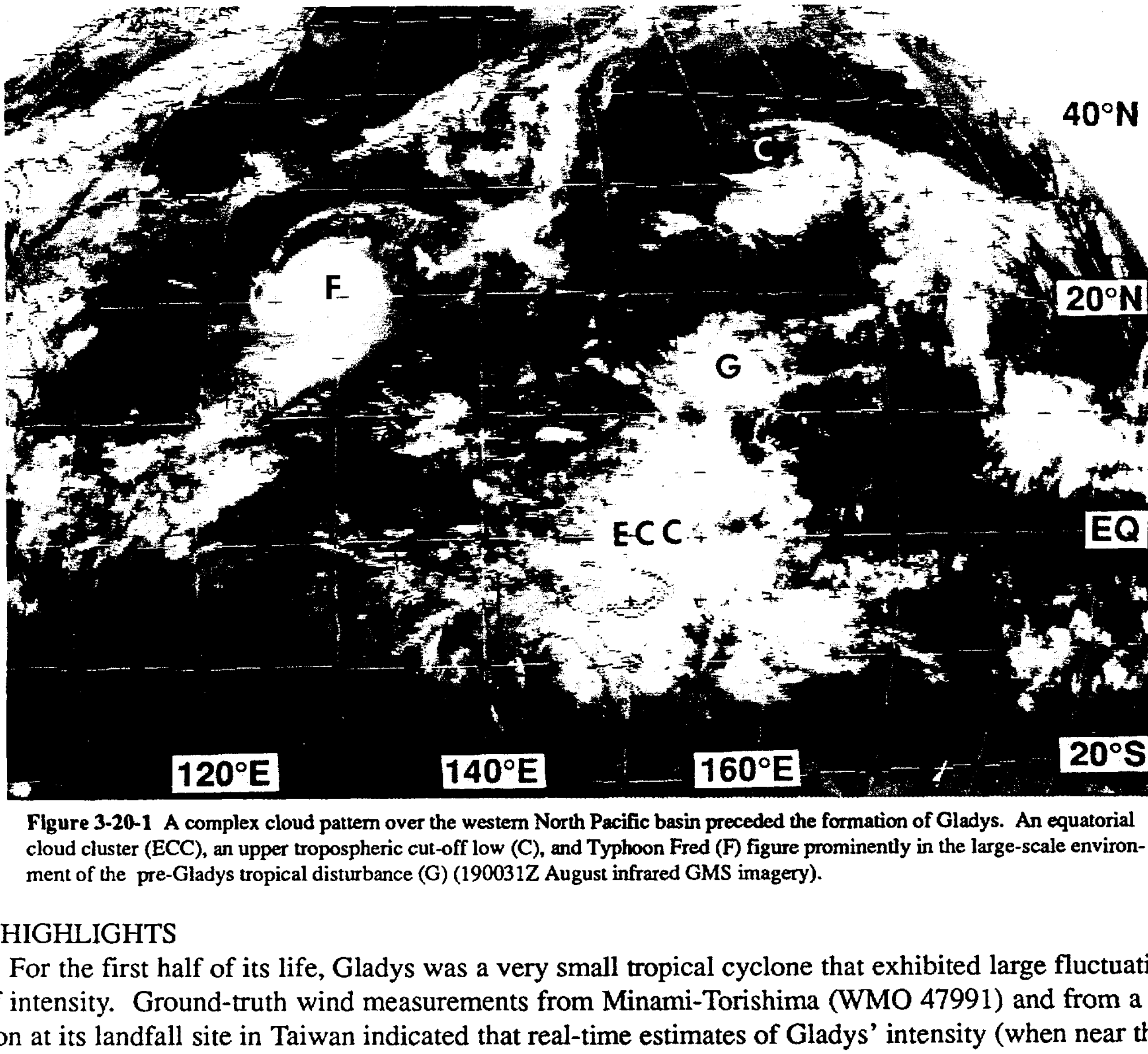

Figure 3-20-1 A complex cloud pattern over the western North Pacific basin preceded the formation of Gladys. An equatorial cloud cluster (ECC), an upper tropospheric cut-off low (C), and Typhoon Fred (F) figure prominently in the large-scale environment of the pre-Gladys tropical disturbance (G) (190031Z August infrared GMS imagery).

I. HIGHLIGHTS

For the first half of its life, Gladys was a very small tropical cyclone that exhibited large fluctuations of intensity. Ground-truth wind measurements from Minami-Torishima (WMO 47991) and from a station at its landfall site in Taiwan indicated that real-time estimates of Gladys' intensity (when near these sites) were too low. Images from Taiwan-based radar showed that as Gladys approached Taiwan it had well-developed concentric eye walls.

II. TRACK AND INTENSITY

As Gladys was forming, the large-scale distribution of cloudiness (Figure 3-20-1) and the large-scale structure of the troposphere over the western North Pacific had become quite complex. An upper-tropospheric cold-core low dominated the distribution of cloudiness in the subtropics of the western North Pacific,near the international date line, and had induced an inverted trough of low pressure in the sea-level pressure field there. A weak monsoon trough extended east-southeastward from near Taiwan to about 13°N 160°E. A large cluster of deep convection and associated cirrus debris accompanied monsoonal westerly winds along the equator from 150°E to 160°E.

During the daylight hours of 19 August, a small area of persistent deep convection embedded in anticyclonically curved cirrus debris (Figure 3-20-2) was observed at the eastern end of the monsoon trough where synoptic data indicated the presence of a weak surface circulation. This tropical disturbance was first mentioned on the 190600Z August Significant Tropical Weather Advisory. After drifting northward for almost two days, satellite imagery showed low-level cloud lines wrapping underneath a convective cloud mass. A Tropical Cyclone Formation Alert was issued at 210430Z. The first warning was issued at 220000Z; it stated, in part:

". . . [Tropical Depression] 20W has an organized low level circulation which is partially exposed on the northwest side of the convective cloud mass. The deep convection is displaced less than 30 nm southeast of the cyclone center. This is a small tropical cyclone . . . SSM/I data does not indicate that gale-force winds exist near the center. . . . The NOGAPS model does not analyze Tropical Depression 20W as a distinct feature, nor does it develop the system in the prog series. . . . Climatology favors a peak intensity of less than 55 kt . . . we anticipate that Tropical Depression 20W will reach minimal tropical storm intensity in about 24 hours, and peak at about 50 knots in 60 hours. . . ."

After 221800Z, Tropical Depression 20W made an abrupt turn toward the west. This may have been in response to the sub-tropical ridge building to its north as two upper-tropospheric cold-core lows, one near the international date line, and another near Japan, weakened. After the system turned toward the west, it began to intensify. It was upgraded to Tropical Storm Gladys at 240000Z. By the morning of 25 August, it developed an eye (Figure 3-20-3). About nine hours after the imagery in Figure 3-20-3, Gladys passed about 30 nm (50 km) south of Minami-Torishima (WMO 47991), where a peak gust of 74 kt (38 m/sec) was recorded at 250956Z. Continuing on a westward track, Gladys appeared to come under the influence of westerly shear and weakened considerably (Figure 3-20-4). At 281800Z, its intensity dropped to 40 kt (21 m/sec). As Gladys moved westward toward Taiwan, it underwent a second period of intensification. At 010000Z September, shortly before Gladys' landfall on Taiwan, the intensity reached 105 kt (54 m/sec) (Figure 3-20-5). Gladys increased in size from very small to average during this second intensification phase. While crossing the northern half of Taiwan, Gladys weakened considerably. It then tracked inland over mainland China. The final warning was issued at 020000Z September as Gladys dissipated over land.

III. DISCUSSION

a. Ground-truth intensity verification

Ground-truth verification of Gladys' intensity was obtained at two points along its track: (1) Minami-Torishima (WMO 47991), and (2) northern Taiwan. At 250900Z, Gladys passed about 30 nm (50 km) south-southwest of Minami-Torishima (WMO 47991), (Figure 3-20-6). This island experienced a seven-hour period of sustained gale-force wind. The peak gust of 74 kt (38 m/sec) was recorded at 250956Z, and the minimum sea level pressure of 1001.4 mb was recorded at 250951Z. This peak wind and minimum pressure indicate that Gladys was a typhoon when it passed south of Minami-Torishima. Based on these measurements, the final best-track intensity of Gladys was increased to 65 kt (33 m/sec) from the real-time 55 kt (28 m/sec) satellite-derived estimate.

The second ground-truth verification was obtained when Gladys came ashore in northern Taiwan. Suao (WMO 46706), recorded a peak gust of 133 kt (68.6 m/sec) at 010232Z and a minimum sea level pressure reading of 960.3 mb at 010247Z. The over-water one-minute sustained wind speed associated with a 133 kt gust is 105 kt (54 m/sec). Thus, the peak gust measured at Suao was used to increase the final best-track intensity to 105 kt from the real-time satellite-derived intensity estimate of 85 kt (44 m/sec).

b. Concentric eye walls

As Gladys approached Taiwan's northeastern coast, weather radar located at Hualien (WMO 46699) was able to gather some detailed images of the structure of its core. From the time when the eye first appeared at the outer range of the radar, until approximately one hour before landfall, the core was comprised of concentric eye walls (Figure 3-20-7). At 311600Z, the inner eye wall was a complete ring about 10 nm (20 km) in thickness that surrounded a small central clearing about 6 nm (10 km) across (Figure 3-20-7c). A 10 nm (20 km) moat surrounded the inner eye wall and separated it from a 10 nm (20 km)-thick outer eye wall. For nearly ten hours, this structure prevailed. There was no evidence of contraction of the outer eye wall. Few tropical cyclones are observed to have well-defined concentric eye walls, although it has been suggested that most very intense tropical cyclones (i.e., those tropical cyclones with intensities in excess of 100 kt) have concentric eye walls at some point in their evolution (Willoughby 1982, 1990). Another observation made by Willoughby is that when concentric eye walls are present, the outer eye wall tends to contract and eventually replace the inner eye wall. In the case of Gladys, it appears that a steady-state structure of well-defined concentric eye walls was maintained for 10 hours. Landfall ultimately disrupted that structure.

c. Forecast performance

The westward-moving Gladys presents an ideal case for illustrating the poleward bias reported by Carr (personal communication) to exist in the NOGAPS model for very small westward-moving tropical cyclones (Figure 3-20-8). According to Carr, NOGAPS effective grid spacing is too large to properly analyze a very small to small tropical cyclone. The bogus vortex inserted into the analysis starts out too large and usually expands if the model intensifies the system. Since the poleward propagation of a vortex is size-dependent (i.e., the larger the vortex, the greater the poleward prop-

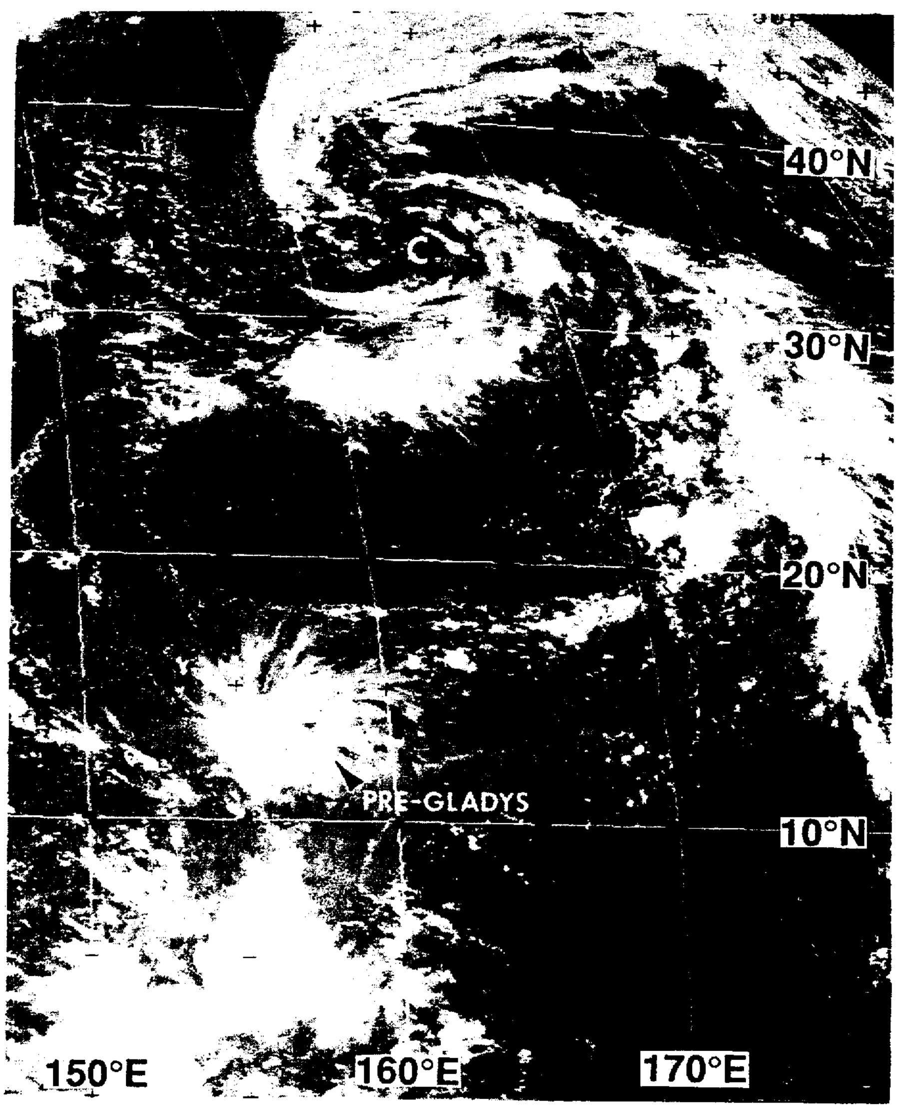

Figure 3-20-2 An area of persistent deep convection associated with anticyclonically curved cirrus outflow, defines the tropical disturbance that would later become Gladys (190031Z August visible GMS imagery). The "C" shows the location of a large upper-tropospheric cut-off low.

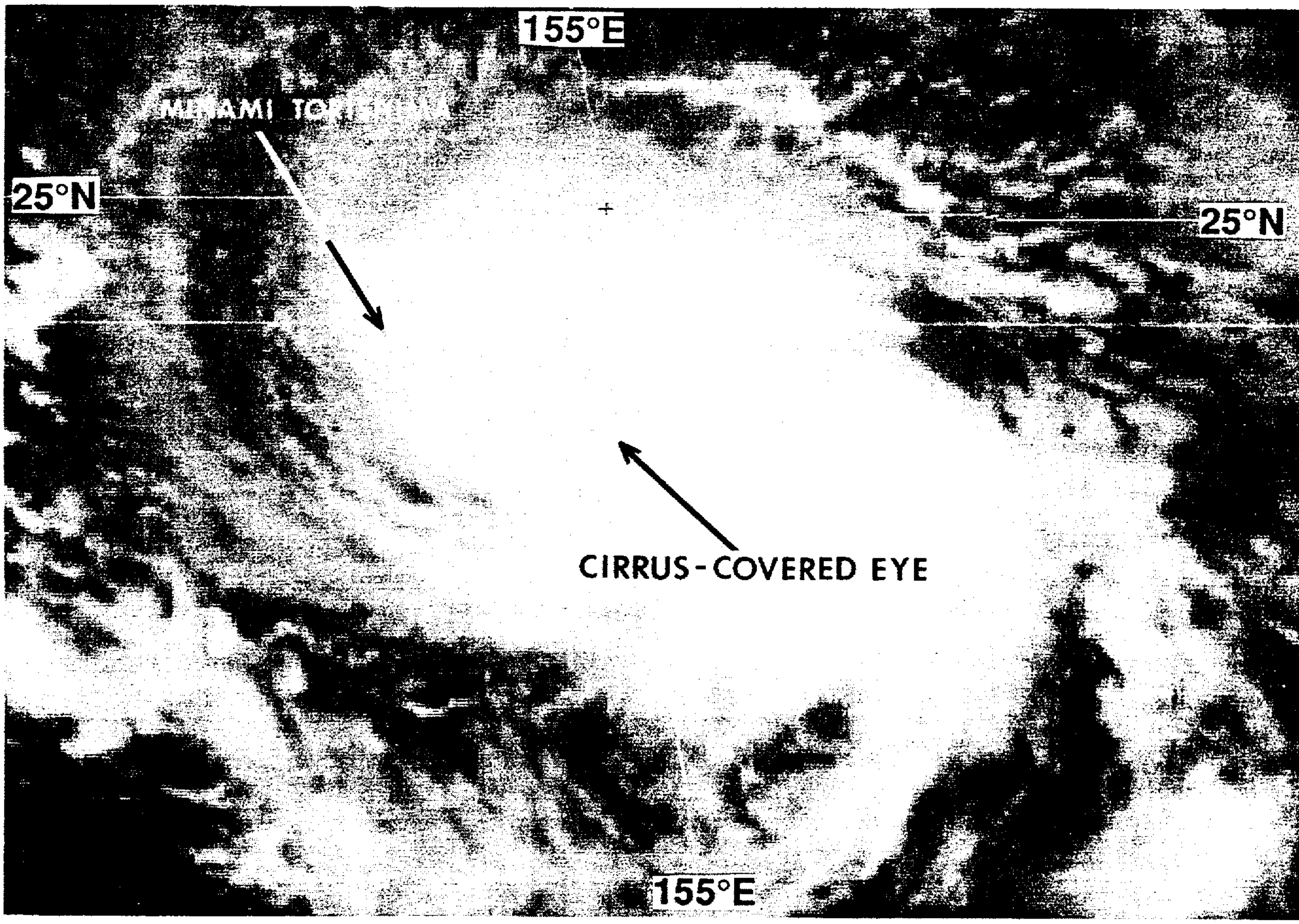

Figure 3-20-3 An eye appears in Gladys' central dense overcast (250131Z August visible GMS imagery).

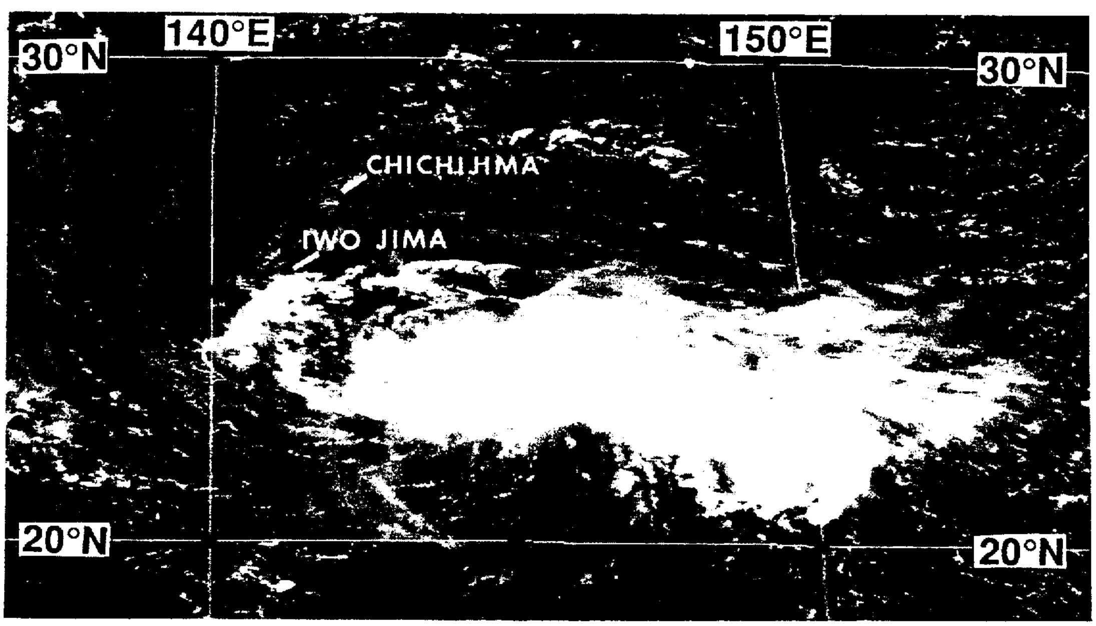

Figure 3-20-4 Gladys' low-level circulation center becomes partially exposed as the system experiences westerly shear (280031Z August visible GMS imagery).

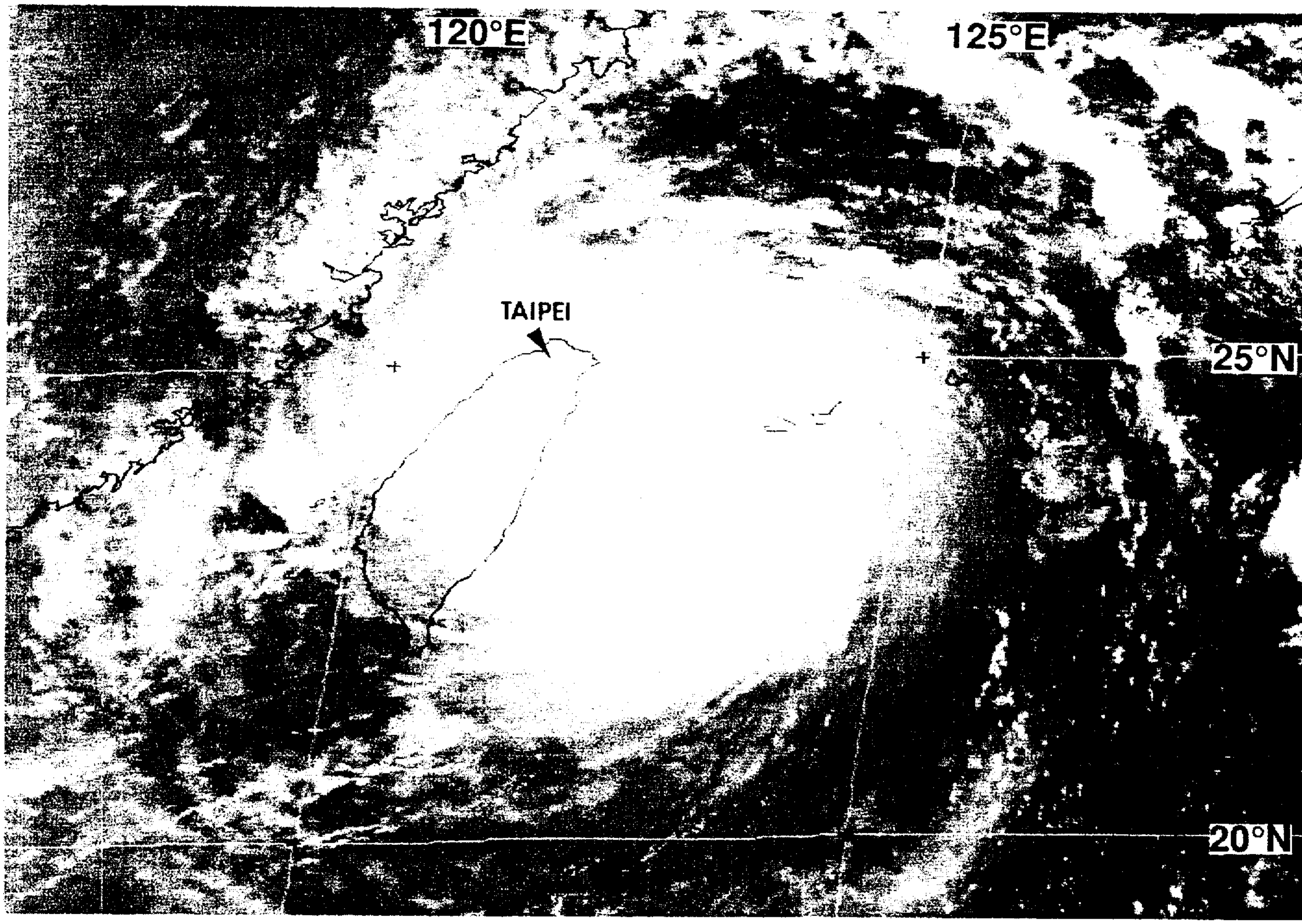

Figure 3-20-5 Gladys at peak intensity (312331Z August visible GMS imagery).

agation), it is almost a guarantee that the NOGAPS forecast will be to the right of track for a very small westward-moving tropical cyclone.

IV. IMPACT

Typhoon Gladys battered Taiwan with high wind and heavy rain. A peak wind gust of 133 kt (68.6 m/sec) was recorded at Suao (WMO 46706). Six deaths were recorded. A woman was killed when a utility pole fell on her car, a man drowned in a flooded river, and three other people were killed by falling objects. Another woman was killed when strong winds caused her house to collapse.

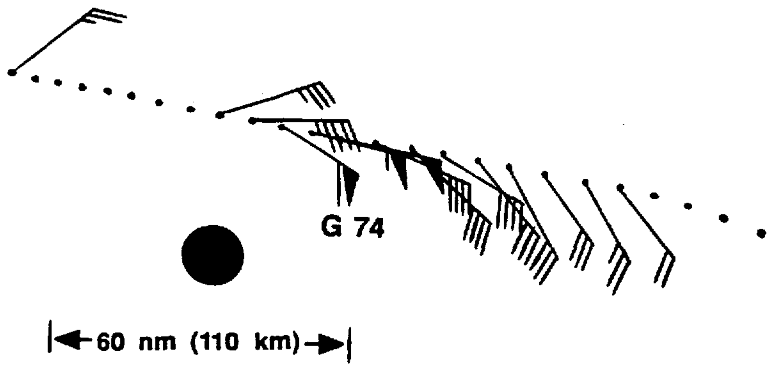

Figure 3-20-6 The wind recorded at Minami-Torishima (WMO 47991) as Gladys passed to the south (each small dot is a one-hour time step). The reference frame has been adjusted to the center of Gladys (large black dot).

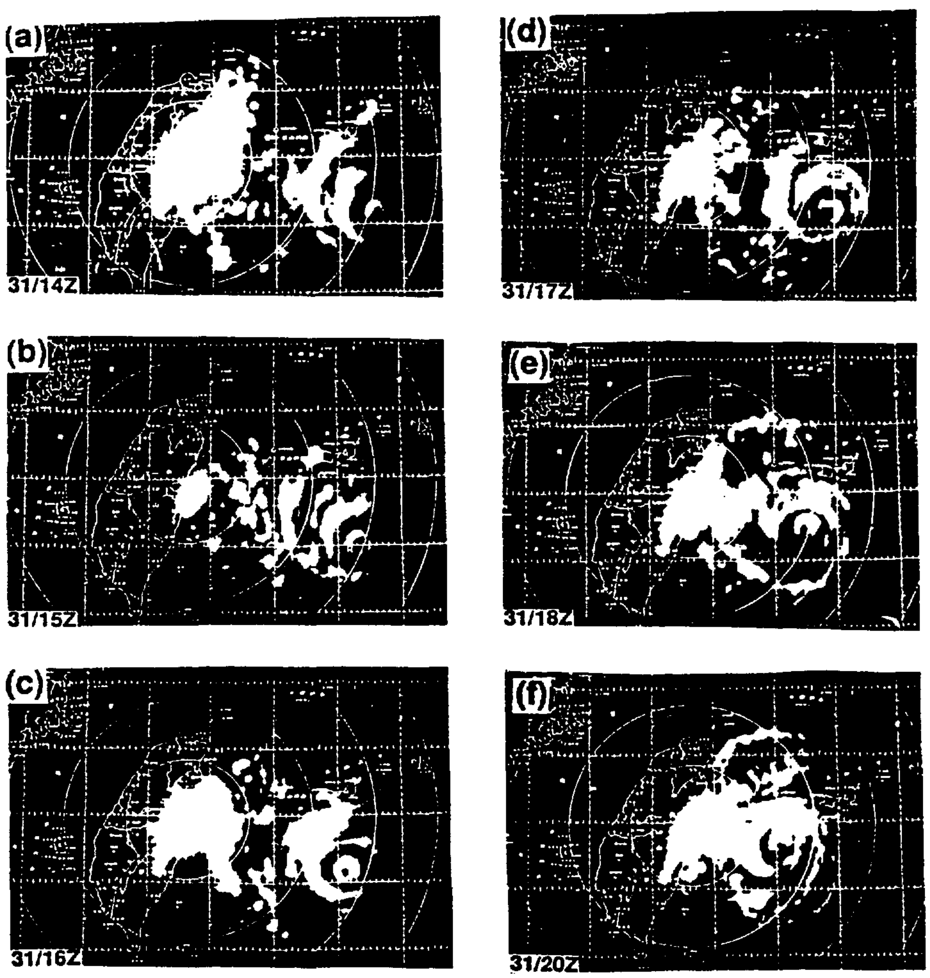

Figure 3-20-7 (a-f) Ground-based radar depictions of the concentric eye walls of Typhoon Gladys as it neared the coast of Taiwan. Time of radar image is indicated on each panel. (Radar images courtesy of the Taiwan Central Weather Bureau.)

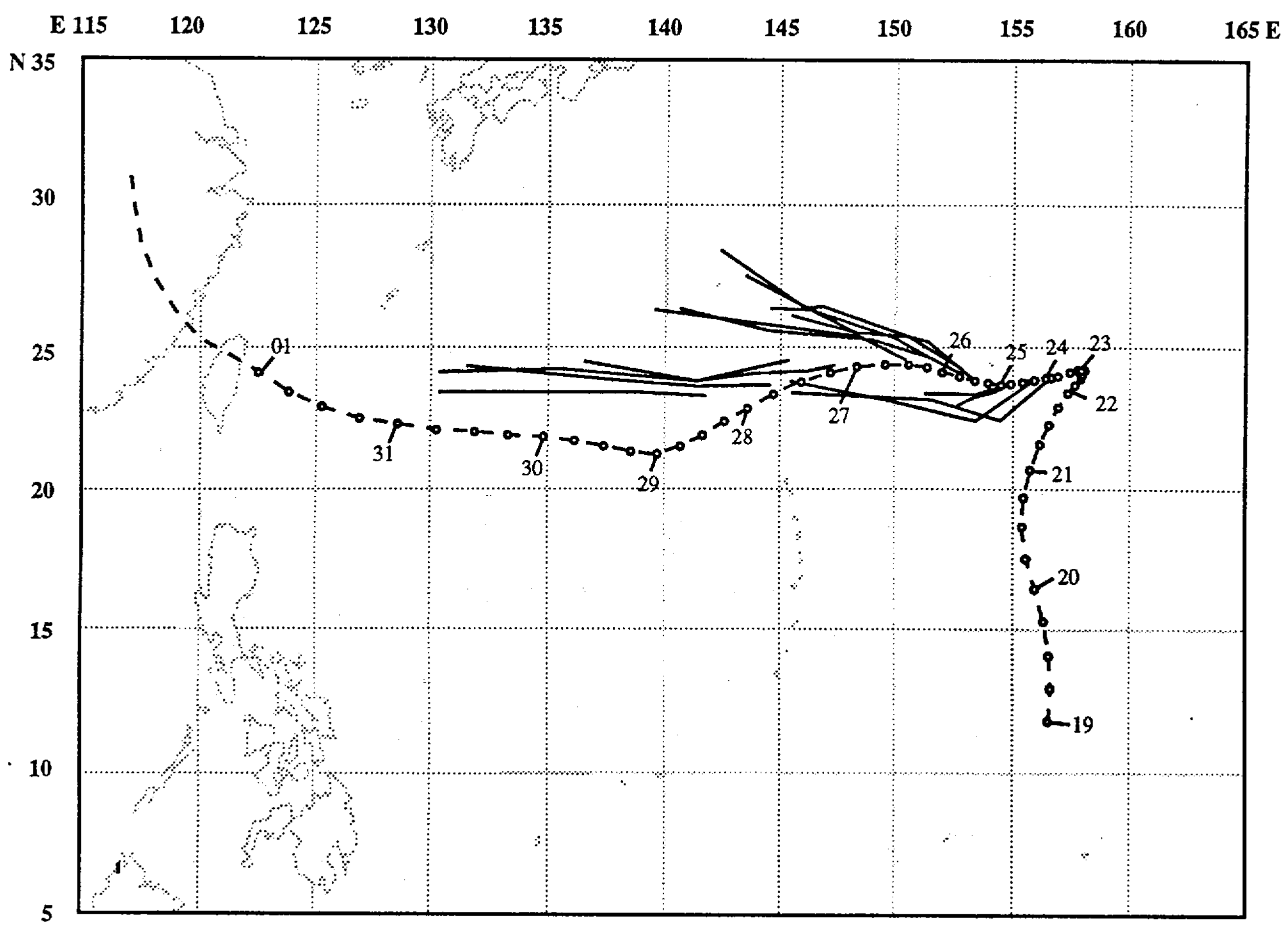

Figure 3-20-8 NOGAPS track forecasts show poleward bias.